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Publication date:
2015

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Bendtsen, J., Owen-Falkenberg, M., Pedersen, J. O. P., Mortensen, J., & Rysgaard, S. (2015). *Optimizing current fields, sea level and chlorophyll from regional modelling and remote sensing*. Poster session presented at 18. Danske Havforskermøde, Copenhagen, Denmark.

Optimizing current fields, sea level and chlorophyll from regional modelling and remote sensing

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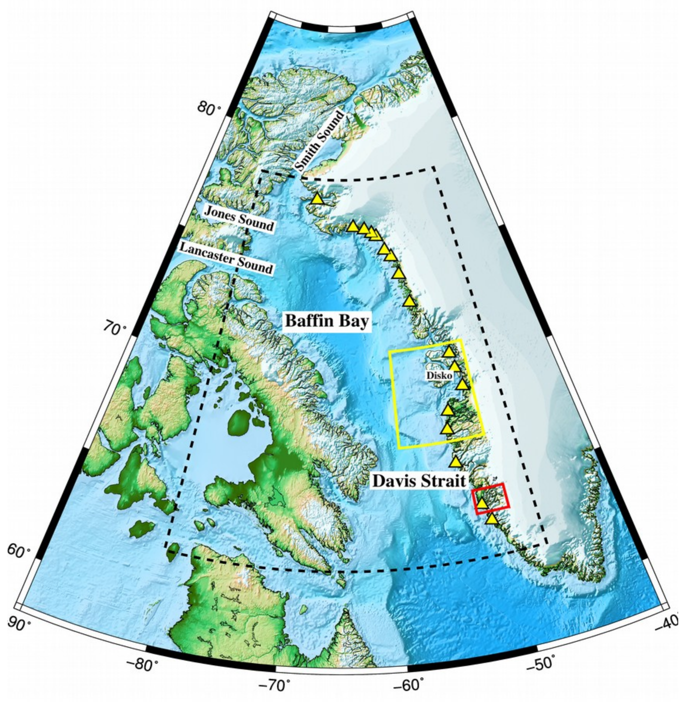
Regional modelling

The regional model is based on the ocean circulation model system COHERENS (Luyten, 2013) and it solves the three-dimensional hydrodynamical equations in a finite difference numerical grid. The ocean model has been applied in studies of various marine areas, including studies around Greenland (Bendtsen et al., 2014).

In the Baffin Bay model setup presented here, the 3D-fields of current velocities, temperature and salinity are described with a spatial resolution of ~5x5 km (i.e. 2.7'x2.7'). The vertical resolution is determined by 30 vertically stretched sigma layers. Initial conditions and open boundary conditions of temperature and salinity are determined from ocean climatology (WOA13).

Transports through the open boundaries are specified according to the estimated annual transports (Tang et al., 2004) through Lancaster Sound, Jones Sound and Smith Sound and are prescribed as 1.1, 0.2 and 0.9 Sv (1 Sv = 10^6 m^3 s^{-1}) into the Baffin Bay, respectively, and the transport at 62ºN is specified to ~20 Sv northward towards Davis Strait.

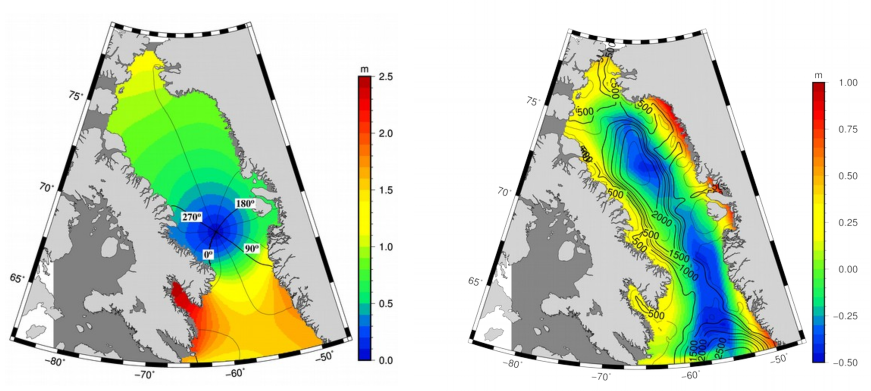


Meteorological forcing and sea ice
Meteorological forcing is obtained from the NCEP re-analysis data set for the period in 2013 (Kalney et al., 1996). In addition, the daily sea ice cover is applied as an upper boundary condition such that energy fluxes and wind stress are reduced when sea ice is present.

Runoff
Runoff is included from 17 freshwater sources along the coast of Greenland representing the outlets from major fjords and glaciers along the west coast (yellow triangles in the figure). A total annual freshwater runoff of 9 mSv is prescribed.

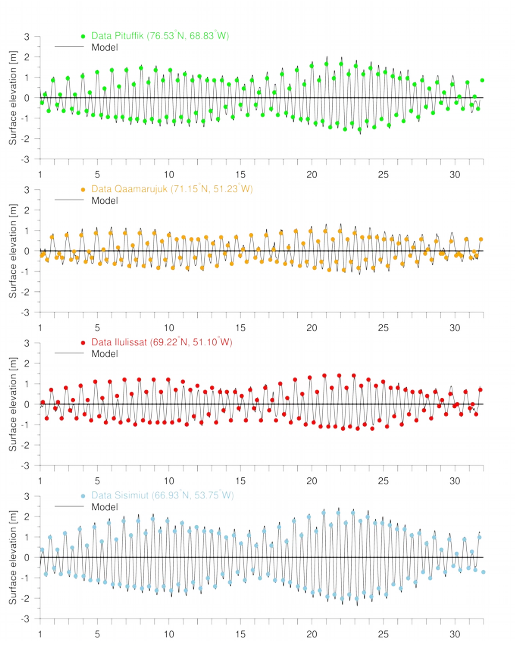
Tidal currents

Tidal forcing is specified by the seven most dominating tidal constituents at the southern boundary. Tidal amplitudes and phases are obtained from tidal analysis of observations in Godthåbsfjord (Mortensen et al., 2011) and applied at the open southern boundary in the model, where the time delay between the boundary (62 ºN) and Godthåbsfjord (64 ºN) is taken into account.



Tidal analysis of model solution in July 2013. (left) The amplitude (color) and phase (contour) of the M2-tidal component show a pronounced amphidromic point centered ~67ºN in the Baffin bay. (right) Residual water level in July (color) and bottom bathymetry (contour).

•Tidal elevation from tables of low and high tides in August 2013 along the west coast of Greenland (bullets) and model simulation of water level (black line). A good accordance between table values and model simulation is seen from all coastal stations north of Davis Strait to the northern coast in Melville bay.



Modelling and remote sensing

Validation of model predictions is a challenge in regions with sparse data coverage and few monitoring stations. Here satellite-based remote sensing data are the only data available that offers a systematic and spatially exhaustive coverage and, therefore, these data are very valuable both for model verification and model input.

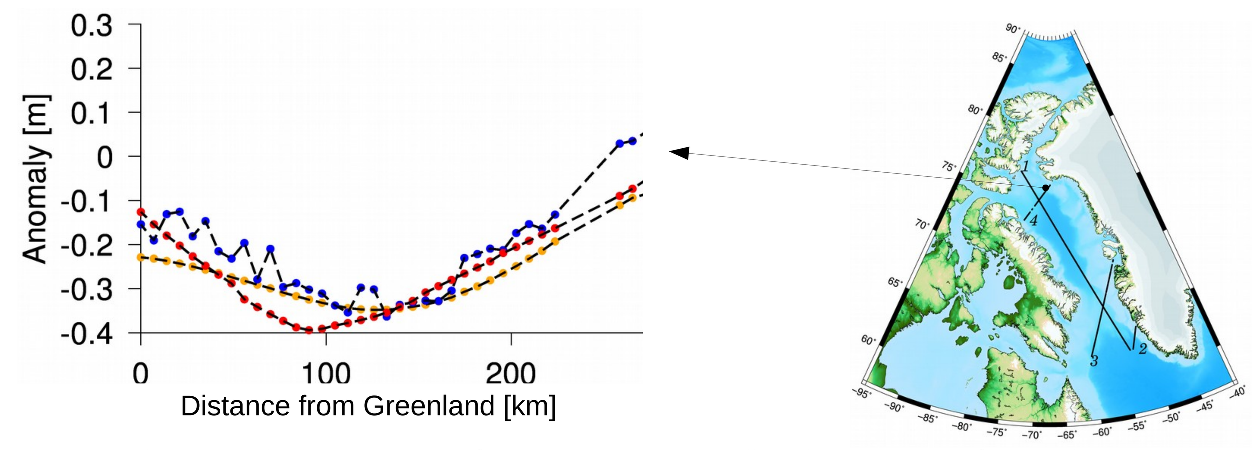
In particular satellite altimetry offers high precision data that can simultaneously produce insight into shortcomings of the models and provide an estimate of the relative error budgets of the models and observations. Here we present results from an analysis of both satellite measurements and high-resolution numerical ocean simulations from the Baffin Bay area.

Improved analysis of ocean circulation are necessary for monitoring effects of climate change around Greenland, e.g. changes in freshwater content in the surface waters, and for planning of activities at sea.

Sea level anomaly

Satellite measurements provide anomalies of sea level height in relation to a reference sea level, i.e. referred to as sea level anomaly (SLA). Tidal corrected SLA provides an estimate of the SLA where the tidal signal has been removed from the SLA-measurements, and this signal can be directly compared to a corresponding model-derived mean sea level height where the tidal signal, correspondingly, has been filtered out.

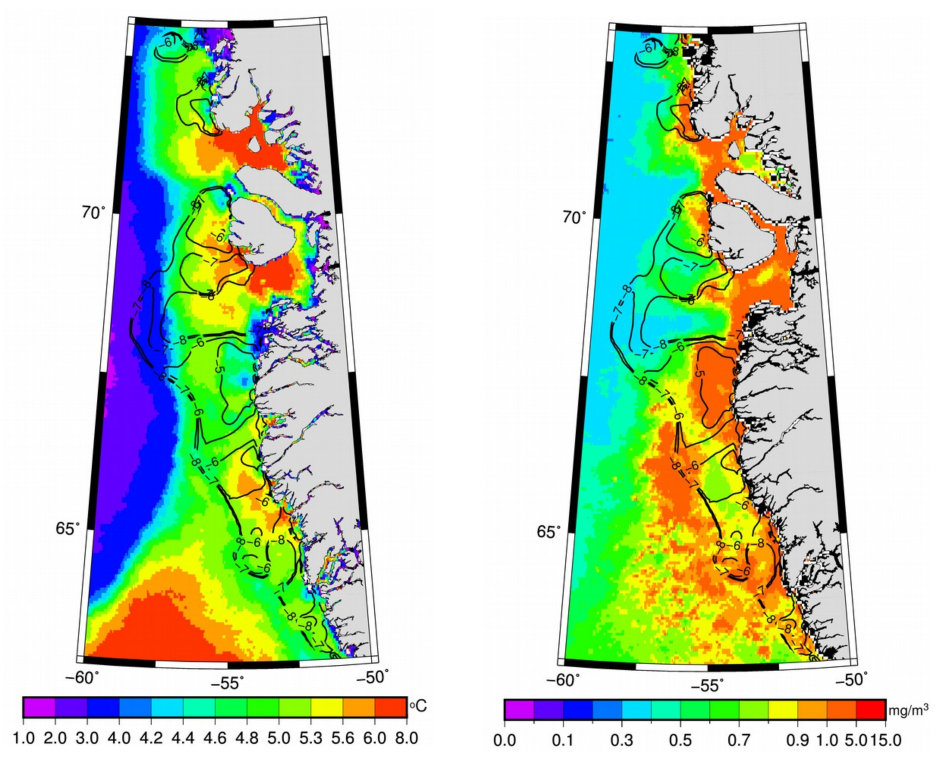
The example below of a comparison between tidal corrected sea level from the model (red) and from the SARAL satellite (blue) in July 2013 shows a general accordance near Greenland (i.e. distance = 0) towards Baffin Island (Track #4).The satellite measurements, therefore, supports the simulated westward average current field near the Greenland coast across the transect.



Tidal corrected sea level measurements from the SARAL satellite along track #4 from July 2013 (blue) and the corresponding simulated tidal corrected sea level in July from the model (orange). Satellite measurements of SLA are added to the reference field of mean dynamic topography (DTU10mdt, orange).

Satellite SST & chlorophyll

Tidal motion is damped due to friction along the ocean bottom and our model simulation (contour lines) shows that large amounts of energy are dissipated on the shelf areas in the south-eastern part of the Baffin bay. The energy dissipation is concentrated above the banks near and north of Davis strait. Comparison with satellite SST values in July show that areas above relatively shallow banks and with large energy dissipation (e.g. St. Hellefiske Bank, ~67.5 N), and thereby elevated vertical mixing, are associated with cold surface waters. Chlorophyll fields in September also show a similar correspondance between areas with high chlorophyll values and high energy dissipation at the bottom.



- (left) Monthly climatology from AQUA, MODIS (2002-2014) of averaged SST in July (colors) and model simulation of monthly averaged energy dissipation at the bottom (contour, $\log_{10}$(W kg^{-1})).
- (right) Monthly climatology from AQUA, MODIS (2002-2014) of averaged chlorophyll in September (colors) and model simulation of monthly averaged energy dissipation at the bottom (contour, $\log_{10}$(W kg^{-1})).

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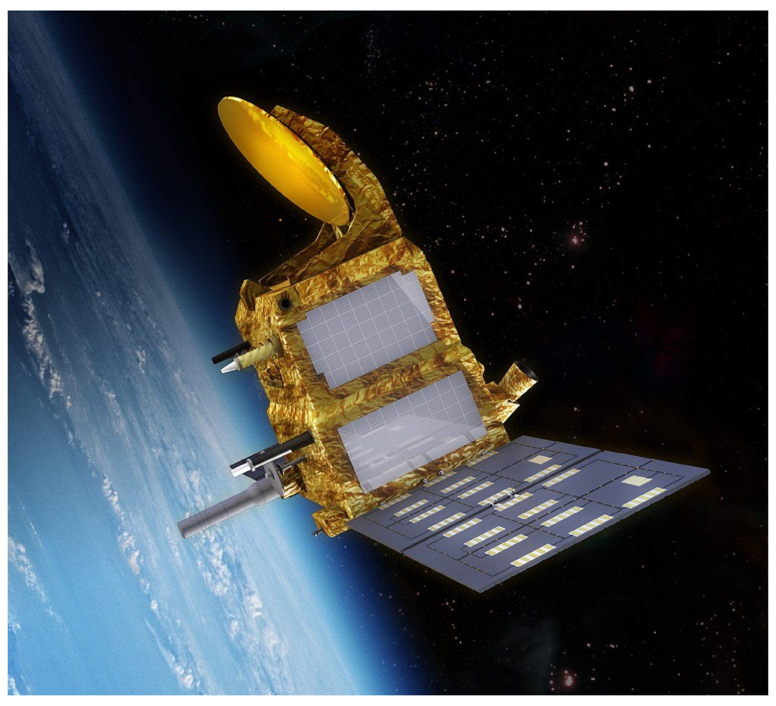
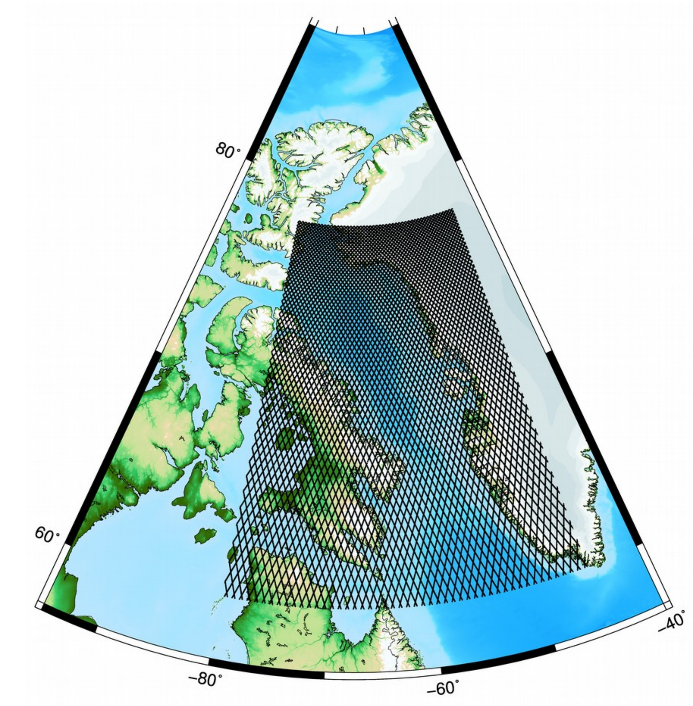
Satellite altimetry



We apply remote sensing data from the SARAL satellite. SARAL is a cooperative altimetry technology mission between the Indian Space Research Organization (ISRO) and the french CNES (Space Agency of France) and was launched into a sun-synchronous orbit 25th of February 2013.

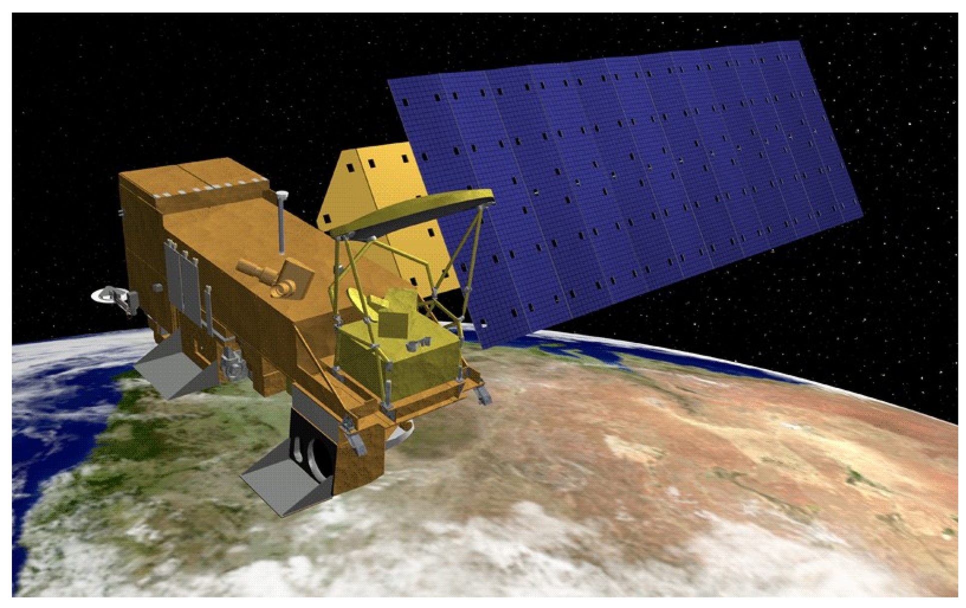
The Altika altimeter measures the ocean surface topography with an unprecedented accuracy of 8 mm and, thereby, it represents a significant improvement in comparison with the average accuracy of other current-generation altimeters (~2.5 cm), and also it has a relatively high spatial resolution of only ~2 km. After a SARAL repeat cycle (i.e. 501 passes) the satellite passes the same ground track within ±1km every 35 days. Therefore, SARAL satellite data are very suitable for studying ocean currents, mesoscale ocean processes and transports.



All SARAL satellite passes over the coast off West Greenland and the Baffin Bay area in July 2013.

Satellite SST & Chlorophyll

Satellie derived sea surface temperature (SST) and Chlorophyll are here obtained from the AQUA satellite equipped with a MODIS sensor (Moderate resolution imaging spectroradiometer). We apply the monthly average level 3 processed SST and chlorophyll-a data in the period 2002-2014 and from these monthly climatologies have been made. The spatial resolution is 4x4 km.



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